2.16 SITUATION ASSESSMENT

An important function performed by all simulated pilots is the updating of their individualized mental models using the information presented to them by their various sensor systems. This updating falls into two broad classes, the updating of physical parameters and the updating of the pilot's assessment of his situation. This section describes the latter.

The pilot's assessment of the current situation involves the evaluation of many derived variables that define its various aspects. For example, functions are evaluated which reflect the assessed intent of other aircraft, the degree to which one aircraft is threatened by another, and the probability that an aircraft has been detected by a hostile flight. These variables are generally expressed as either “surrogate probabilities” or as expected aircraft values. A surrogate probability is a number in the range 0-1 that may be thought of loosely as the probability that an event will occur. The term “surrogate” is used because the number is generally heuristic in nature and rarely in correspondence with the actual probability of the event. The computed value of the number is, however, sensitive to many of the factors that the actual probability would also be dependent upon.

2.16.1 Functional Element Design Requirements

This section presents requirements necessary to implement the Situation Assessment FE. This function will simulate updates to the situational awareness of a pilot via a process of prioritizing received messages, computing measures and probabilities that can bias or add significance to subsequent decisions, and replacing information in data arrays that can be accessed during the decision making process. The function will be executed repeatedly for each pilot in the simulation so that a model of current situation assessment can be maintained over the course of simulation execution.

a. Brawler will simulate receipt and processing of messages by the pilot. These will include intent-to-fire messages, orders issued by flight leaders or controllers, and other messages that provide information about the engagement, mission, or tactics.

b. Brawler will simulate pilot assessment of self engagement measures including probabilities of kill and survival, intrinsic and effective values of killing other aircraft and being killed by them, and utility of engagement values. These measures will be used to influence the decision making process by increasing or decreasing the relative weights of factors included when alternatives are scored and ranked.

c. Brawler will simulate other situational variables needed by flight leaders that pertain to risk and safety of all aircraft in the flight. These will include a probability of having been detected by hostile sensors and values employed in decisions relating to flight posture and orders issued by the leader.

d. Brawler will simulate pilot assessment of damage to the aircraft, which will be used when making posture and weapon decisions.

e. Brawler will simulate pilot assessment of missiles, launchers, and targets by computing values associated with each aircraft in the scenario. These will be used to influence weapon choice and firing decisions.

f. Brawler will simulate inferred detections that result from actions or results not observed or presented by sensor displays.

g. Brawler will simulate pilot assessment of incoming IR missiles which will inhibit decisions to increase throttle settings or use of afterburner.

These requirements will be satisfied by the combined implementation of the design elements described in the following section. They were inferred from knowledge of how the existing models currently perform the Situation Assessment function.

2.16.2 Functional Element Design Approach

Design Element 16-1: Process Intent-to-Fire Messages

Design Element 16-2: Process Orders

Design Element 16-3: Prioritize Others

Design Element 16-4: Self Engagement Measures

The situation assessment variable called *sem2*(i,j) is the surrogate probability that aircraft i can kill aircraft j, given that i is attacking j and no other aircraft are involved in the combat. This variable is a function of the aircraft geometries (range, aspect angle, altitudes, speeds, etc.), the aircraft overall combat effectiveness factors, and characteristics of the weapons (range, all-aspect, and lookdown capability) carried by the attacking aircraft. It varies with these attributes of the situation in the same direction as would the actual probability. For instance, as the aspect angle of aircraft j decreases at shorter ranges, the value of *sem*(i,j) will increase.

Design Element 16-5: Probabilities of Attack and Kill

The variables *patk*(i,j) and *pkil*(i,j) are surrogate probabilities that aircraft i will attack and kill aircraft j. An heuristic function, *patk*(i,j) is designed to be sensitive to probability of detection, range, one-versus-one measures, and off-boresight angle. The *patk*(i,j) values computed as the products of these four terms are normalized so that:

$$\sum_j patk(i,j) = 1.0$$

pkil(i,j) is the product of the conditional probability that i will kill j given that i attacks j, *sem2*(i,j), and the probability that i will attack j, *patk*(i,j).

Design Element 16-6: Probability of Survival

Other situational variables of interest are *psrvfl*(*i*) and *psrv*(*i*), which give the probabilities that aircraft *i* will survive the engagement. They differ if aircraft *i* is hostile to the pilot evaluating these variables (the "conscious" pilot) in that *psrv*(*i*) does not include the chance that the conscious aircraft is the one that kills aircraft *i*. An initial estimate of *psrvfl*(*i*) is given by:

$$psrv0f(i) = \prod_j \{1 - pkil(i,j)\}$$

This estimate is obviously low in that it does not take into account the chance that an attacker *j* will be killed before it completes its attack. The chance an attacker *j* will survive long enough to complete its attack is computed as the geometric mean between 1.0 and *psrv0f*(*j*). The final estimate of *psrvfl*(*i*) is then given by:

$$psrv0(i) = \prod_j \left\{1 - pkil(i,j)\left[psrv0f(j)\right]^{1/2}\right\}$$

Design Element 16-7: Intrinsic Value and Value Killed

The situational variable *vkexp*(*i*) is the expected value that aircraft *i* will kill *j*, given that *i* survives. It is given by:

$$vkexp(i) = \sum_j valint(j)\,pkil(i,j)$$

where *valint*(*j*) is the intrinsic (user input) value of aircraft *j*. The intrinsic value may be thought of as the number of points you get for killing an aircraft of a given type, or the number of points lost when a friendly of a given type is lost, *when evaluating results after the engagement has ended*; they are long-term values associated with each aircraft.

Design Element 16-8: Effective Value

While each aircraft has an intrinsic value, things an aircraft is doing in the context of the current situation make the instantaneous value of attacking that aircraft differ from the aircraft's long-term value. An effective value, *valeff*, associated with the aircraft's current value, is used for decisions with a short time frame (the majority of Brawler decisions). It differs from the intrinsic value only for hostiles. *Valeff* consists of a value adjusted for the situation and an 'order value', *valord*, that reflects order priorities. The value adjusted for the situation and orders is given by:

$$valeff(i) = \left[valint(i) + vkexp(i)\frac{psrv(i)}{psabg} + valord(i)\right]$$

where *psabg* is the average survival probability for hostiles. Thus, a hostile that threatens friendlies, because it has a higher than normal *vkexp*, has an enhanced *valeff*. Also, a higher than normal *psrv*(*i*) will enhance *valeff*(*i*). The function of *valeff*(*i*) is to induce the conscious pilot to attack or neglect aircraft *i* when such behavior is appropriate. The variable *valefl*(*i*) is used by flight leaders to generate and choose between flight tactics and postures. *valefl*(*i*) is given by:

$$valefl(i) = valint(i) + vkexp(i)psrvfl(i)$$

There is no term that accounts for orders because the flight leader is the highest commander simulated. If the mission dictates that one kind of hostile is more important than another, this can be reflected by the user setting of *valint* for the various hostile types. The *valord* term used by subordinates is time-dependent. The objective here is to make sure that subordinate value functions are reasonable in the absence of orders. A subordinate, due to communications jamming or for other reasons, may not receive updated orders for a long time. In such cases a live pilot would realize that a very old directive to attack a particular hostile should be discounted. Brawler accomplishes this by making *valord* the product of the originally received order value and a decreasing function of the time since the order was received.

Design Element 16-9: Utility Functions

uatk(*i*), *uevd*(*i*), and *ueng*(*i*) are defined for hostiles and express the expected utility (value) accrued by attacking, evading, and engaging hostile *i*. They are used, directly or indirectly, in many Brawler pilot decision algorithms. *uatk*(*i*) is given by:

$$\mathrm{uatk(i) = valeff(i)sem2(me,i)}$$

where *me* is the index of the conscious pilot. *uevd*(*i*) is given by:

$$\mathrm{uevd(i) = pkil(i,me)valme}$$

where *valme* is the conscious pilot's intrinsic value. *ueng*(*i*) is the sum of *uatk*(*i*) and *uevd*(*i*):

$$\mathrm{ueng(i) = uatk(i)+uevd(i)}$$

Design Element 16-10: Probability of Having Been Detected

The variable *pseen*(*i*), currently used by flight leaders, attempts to estimate the probability that a friendly aircraft *i* has been detected by any hostile. This is done by assuming a combination Markov-Bayesian model in which the detection rate for a friendly by hostiles causes a Markov-type transition from a nondetected to a detected state. An update for the probability that the flight as a whole has been detected is also performed.

Design Element 16-11: Other Situational Variables

Other situational variables that are used only by flight leaders are the variables *risks*, *kills*, *riska*, and *killa*, which are used when making the flight posture decision.

The risk variables indicate expected value to be lost in an engagement, and the kill variables the expected value of hostiles to be killed. The postscript “*s*” stands for situational assessment: the geometries of the opposing forces are considered, so the situational versions *risks* and *kills* are thought of as short-term predictions. The “a” postscript stands for *a priori* assessment: only the effective force ratio of the two sides is considered. These variables are used by the flight posture decision projection routine to help predict the overall expected *risk* and *kill* (no suffix) for various flight postures under consideration. Those that involve longer term engagements give a higher weight to the *a priori* values, while those that involve a quick exit give higher weight to the situation values *risks* and *kills*.

Design Element 16-12: Damage

A rudimentary model of aircraft damage has been added which influences a pilot's behavior if he is assessed as damaged. This first-cut at an aircraft damage model is the framework for a more comprehensive model and contains no internal mechanism to damage an aircraft. It is recognized that there is an extensive range of damage (from minor to catastrophic), however, no attempt has been made to model performance degradations due to damage. The variable, *damage,* has been introduced which currently is a flag for whether or not an aircraft is damaged (i.e., 0 for undamaged and 1 for damaged) and may be controlled by Production Rules only. This model affects only the pilot's flight posture and weapon fire decisions.

When an aircraft is assessed as damaged, the flight posture decision is to be biased towards the aircraft disengaging. If there is a weapon shot available to the pilot in the damaged aircraft, his weapon fire decision is to be influenced such that he will take his shot prior to disengaging rather than pressing in closer to improve his shot.

Design Element 16-13: Missile State

Missiles enter the mental model of the launching pilot upon the firing the missile. For all other participants, missiles must be observed visually, by radar, with a radar warning receiver (RWR), with a missile launch warning device (MW), or through a message received from a flight mate.

The detection of a failed missile requires special attention. A large number of failure modes exist by which a missile may become ballistic. The ability to sense that a missile is ballistic is a function of the failure mode. The driving distinction is guided by how quickly an observer would be able to determine that the missile is ballistic. For example, if a pilot "detects" a missile which has had a guidance start-up failure, a fuzing failure, its target killed, or illumination lost, the pilot immediately senses that the missile is ballistic and removes it from his mental model. For other failure modes such as seeker angle limit exceeded, seeker rate exceeded, guidance shutdown on time limit, or control loop gain saturation, the flight path may appear to be guided, at least for a short time. Accordingly, the missile is detected as "live" until a time interval has elapsed since the missile was first detected in this state. The interval is calculated as the time required to impact the pilot's assessment of the missile's intercept plus five seconds.

Design Element 16-14: Launcher

For each candidate, a value equal to the cosine of the angle between the missile/candidate relative velocity and relative position vectors is taken. The candidate with the smallest angle is taken as the launcher, provided the angle is less than 30˚. If the angle is larger, the conscious pilot does not select a launcher. The exception to this scheme occurs if the missile is launched by the conscious pilot. In this case, the pilot always recognizes himself as the launcher. When a missile is detected and a launching aircraft cannot be determined from those aircraft known to the observer, an "inferred" detection of the launcher takes place which is similar to the case where an undetected missile kills a friendly aircraft. The reason for this is also similar: The pilot must recognize that the sighting of a missile is a positive indication of a hostile attack.

Design Element 16-15: Target

If a detected missile is one which the conscious pilot has launched, he always knows the identity of the target. For all others, the target is chosen through a value function evaluated for each target candidate. The value is a function of factors such as the steering error between the current missile velocity vector and the intercept solution based upon a nonmaneuvering target and a constant speed missile, time to intercept, launches by friendlies vs. hostiles, and hysteresis based upon prior detections. The target with the highest value is chosen as the missile target.

Design Element 16-16: Inferred Detection

The Brawler situation assessment logic provides for “inferred” detections previously undetected hostiles responsible for killing shots. Whenever a friendly is detected as having been killed, a pseudo detection of the hostile that did the killing (similar in form to an observational message) is generated, so that the hostile will be added to the mental model. This somewhat overstates the inferential capacities of the pilot, since he cannot mistakenly assume that the shot is due to another, already known hostile, but it captures the effect to a first order approximation, and seems to work in practice.

Design Element 16-17: Throttle Limiting

If the pilot believes that there is an IR missile targeted at him or that he is within the launch envelope of a threat that may possess IR missiles, he will be inhibited from using his afterburner. This determination is made by first examining all missiles that the pilot believes to be targeted at him. If any of these are known to have IR seekers, or if their type is unknown, then throttle limiting is imposed. Otherwise, all hostile aircraft are examined. Any known not to possess IR missiles are discarded. Of the remainder, any that have been recently observed visually are discarded on the assumption that a missile launch would also have been observed. For all others, an aimpoint calculation is performed and throttle limiting is imposed if the hostile has been in a position to fire a missile at any time within the past fifteen seconds.

2.16.3 Functional Element Software Design

TBD

2.16.4 Assumptions and Limitations

TBD

2.16.5 Known Problems or Anomalies

TBD